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ENGINEERING & ECONOMICS RESEARCH, INC.

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Comparative Analysis
of Geographic Information Systems
Phase II Report

9 August 1985

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Report Number- EER-B02

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August 9, 1985

Ballistic Missile Defense Systems Command
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P.O. Box 1500
Huntsville, AL 35807

Dear Sirs:

Engineering and Economics Research, Inc. is pleased to submit three copies of our report, **"Comparative Analysis of Geographic Information Systems, Phase II Report, dated 9 August 1985"**. This is done in accordance with the requirements of contract DASG60-84-C-0014, "Geographic Information Systems (GIS) Comparative Analysis."

Sincerely,

Duane H. Uken
Manager, Systems Engineering

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This is the PHASE II report of a Comparative Analysis of Geographic Information Systems. The goal of the Comparative Analysis was to make recommendations of the attributes necessary in a GIS to meet the Ballistic Missile Defense Systems Command's needs during the Comprehensive Site Analysis Process. Phase I narrowed the GIS to four using a mailed survey and cluster analysis of attributes. These four in turn were subjected to an in depth analysis. Due to its unique position in the GIS field, ARC-INFO was recommended for an immediate procurement strategy. Benchmark testing between industry leaders was recommended if

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Comparative Analysis

of Geographic Information Systems, Phase II

Table of Contents

1.0 INTRODUCTION

Consistent with the requirements of contract DASG60-85-C-0014, Phase II of the Comparative Analysis of Geographic Information Systems has been completed by Engineering and Economic Research, Inc. (EER) and Engineering Analysis, Inc. (EAI). The goal of Phase II was to analyze the four geographic information systems (GIS) that were determined significant in Phase I, determine those salient attributes applicable to the Comprehensive Site Analysis Process, and recommend those attributes that would be adaptable to a BMDSCOM GIS. The seven design areas in which comparative analysis was performed were: (1) management, (2) applications, (3) process, (4) hardware and software, (5) personnel, (6) costs, and (7) data and data sources.

Each individual GIS that was examined in Phase II will be discussed in Section 2; the TVA Geographic Information Services, the Kentucky Natural Resources Information System, the Bureau of Land Management's Denver Service Center, and the Geographic Management Information System, ESL. This represents systems from Intergraph, ESRI, MOSS, and ESL, respectively. Additionally, since the US Geological Survey utilizes three of these four systems, a site visit and interview was conducted there in order to gain insite into a user's comparison of concurrently utilized systems. The USGS is also a major source of digital geographic information and it was determined important to identify the means for future use of this source.

Section 3 is a comparison of each of the systems in terms of the seven design criteria that serve as a basis of future BMDSCOM implementation. Section 4 is an analysis of the attributes of each system in relation to the site analysis requirements. Section 5 is two recommendations for a GIS implementation, one short term, the other long. Section 6 is references used. Appendix A is the Phase II questionnaires.

2.0 SITE VISITS AND INTERVIEWS

Site visits were conducted during the period 14 June 1985 to 3 July 1985. Mike Mullen of EAI conducted the interviews at TVA GIS, Norris, TN and KNRIS, Frankfort, KY. Al Stults of EER conducted the interviews at BLM, Denver, CO; ESL, San Bernadino, CA; and USGS, Reston, VA. The interview worksheets are included as Appendix A and in the Phase II addendum to the CA Data Book. In addition, user's manuals for MOSS, ARC-INFO, and GES were available to aid in the analysis.

Section 2.1 is the analysis of the TVA GIS, section 2.2 is the analysis of the Kentucky Natural Resource Information System, section 2.3 is the analysis of the Bureau of Land Management's MOSS system, and section 2.4 is the analysis of ESL's GMIS. These sections will be arranged in the following order to expedite comparison, (1) hardware and software, (2) management, (3) applications, (4) process/ capabilities, (5) data and data sources, (6) costs, and (7) personnel. Section 2.5 will be a discusion of the visit to USGS.

2.1 TENNESSEE VALLEY AUTHORITY (TVA)

The Tennessee Valley Authority's Geographic Information System staff, which is part of the Natural Resources and Field Services, has operated an Intergraph GIS system since 1980 when it purchased the polygon-based Intergraph GIS system and incorporated the grid cell-based system it had been using into it. In the past few months, TVA has upgraded their GIS to include a larger system computer with greater capacity, along with software improvements and additions. The features of the Intergraph system utilized by TVA and TVA's applications environment are presented in the following sections.

2.1.1 HARDWARE AND SOFTWARE

The recently upgraded Intergraph GIS which TVA now operates consists of the hardware compoonents identified in Table 2-1. The system is based on a minicomputer, the VAX 11/785, with 8 MB of memory. The system uses graphics processors to boost performance. The system has 2250 MB of disk storage as well as a tape drive for data archival. The data input devices include five high precision graphics tables, color workstations, color plotters, standard video terminals, and line printers. It should be noted that the Intergraph GIS is

Table 2-1 TVA's INTERGRAPH GIS Hardware (Major Components)

Quantity	Item
1	Vax- 11/785 with 8 MB of memory
2	Graphics Processors
2	675 MB Fixed Module Disk Drives
3	300 MB Removable Module Disk Drives
2	Interact Color Workstations
5	Interview Color Workstations (42" x 60" high precision digitizing tables)
2	Versatec V-80 Hard Copy Units
1	Versatec Color Electrostatic Plotter (42" wide)
1	Calcomp 965 Pen Plotter
5	Alphanumeric Video Terminals
3	Epson Line Printers
1	800, 1600, 6250 bpi; 125 ips; 9-track Tape Drive
1	Line Printer

highly graphics oriented and utilizes much digitization requiring the numerous workstations. The current hardware can be upgraded with an additional 8 MB of memory and up to two additional disk drives of over 600 MB capacity each. Additional equipment can also be added which will allow up to three more remote graphics workstations.

Major software packages in TVA's GIS are listed in Table 2-2. Some of these packages are Intergraph supplied, others are from the grid cell-based system which TVA incorporated into the GIS, while others are from other GIS software vendors. The recent upgrade improved TVA's capabilities in Digital Terrain Modeling, in architectural areas related to GIS capabilities, and in strictly graphics areas.

2.1.2 MANAGEMENT

The Geographic Information Services staff provides services to other TVA branches in a wide variety of technical areas. These services support projects which include: (1) industrial site screening, (2) forest industry site inventory and marketing, (3) regional air quality monitoring, (4) development of land management plans for TVA reservoir properties, (5) regional fisheries and molluscan investigations, (8) archaeological site inventory, (9) natural areas site inventory, (10) environmental assessment and review, (11) land capability /suitability analyses, and (12) natural resources planning. Since it is a service organization, it is not budgeted as a separate entity within TVA. Rather it is funded by the organizations within TVA which it serves. It operates for all practical purposes as if it were a private consulting firm offering similar services. It must demonstrate to customers both within TVA and within other agencies how its GIS services can be beneficial to that organization. In addition, the Geographic Information Services staff must be able to respond rapidly and efficiently to meet the needs of its "customers". The staff is divided into two basic parts, applications and operational. The operational staff actually performs the services with the assistance of the applications staff. This lends expertise for modeling functions of the system requiring technical decisions about iterative processes.

The major management concerns center about the fact that the organization is an essentially independent entity within TVA and that the GIS is an expensive system which must be used a

Table 2-2 TVA's GIS Software Packages

1. VAX/ VMS Operating System
2. Interactive Graphics Design Software (IGDS)
3. Data Management and Retrieval System (DMRS)
4. FORTRAN 77 for VAX
5. Elastic Body Small Angles Least Squares (EBSALS)
6. Bulk Input Text System
7. World Mapping System (WMS)
8. Grid Data Utilities
9. Distributed Graphics Software (DGS)
10. Graphics Polygon Processing Utilities (GPPU)
11. Digital Terrain Modeling Nucleus Software (DTM)
12. DTM Interactive Surface Edit
13. DTM Earthworks
14. DTM Graphics
15. Edge Matching (EGM)
16. Architectural Production Drawings
17. Engineering Production Drawings
18. Architectural Modeling
19. Space Planning/ Facilities Management
20. Strategic Planning
21. Stack and Block Algorithm
22. GIS/ IMGRID Conversion Program
23. DTM Slope and Aspect Enhancements
24. DTM Earthwork Enhancements
25. Shadow Pattern Simulation Software

great deal in order to justify its cost. In order to do this, the system is operated on two shifts which increases system utilization. This independant status means that the staff must effectively market and utilize the system's capabilities. TVA's organization of the Geographic Information Services staff appears to be appropriate for TVA and for any organization operating a GIS in a mode where it is operated as a service entity for other parts of the organization or outside customers.

2.1.3 APPLICATIONS

TVA uses the GIS to perform services in the twelve general project areas which were listed previously. This subsection is intended to give additional details and examples of TVA applications. During 1984, TVA's Geopraphic Information Services Staff performed 48 projects ranging in scale from just a few hundred acres to regional scale projects. The range of efforts of these projects in monetary terms ranged from thousands to hundreds of thousands of dollars per project. Some of the projects performed involved reservoir plan development services, industrial site screening projects, industrial site inventories, a gypsy moth inventory covering part or all of several states, and a project estimating regional forest biomass. Although these are just a few examples, it is obvious that the range of applications is very broad. While TVA's activities in power plant siting are no longer a consideration for the immediate future, industrial plan siting and nuclear plant maintenance are expected to occupy more of the GIS staff's activities. For that reason, the capabilities in the area of digital terrain modeling, CAD/CAM, and graphics have been supplemented in the recent upgrade.

2.1.4 PROCESS/ CAPABILITIES

The Intergraph GIS which TVA currently operates has the capabilities of an engineering mapping system, a parcel information system, a thematic or statistical mapping system, and combinations of these functions. The Intergraph system as obtained by TVA does not have image processing capabilities. TVA has an image processing capability by way of incorporation of an earlier grid cell-based system into the GIS. Other third-party software exists as well, for additional capabilities in several functional levels including: data

encoding, data editing, data manipulation, retrieval and output, coordinate changes, projection changes, scale changes, overlaying and related functions, grid cell analysis, digital terrain analysis, output, database manipulations, and interactive functions. Table 2-3 summarizes some of the more important of these capabilities.

2.1.5 DATA AND DATA SOURCES

TVA cartographic data comes almost entirely from internal digitization either for the specific project or from databases created for the same area in earlier projects. As much as ninety-five percent of the cartographic data is digitized internally, with only five percent currently being obtained from other agencies or sources. Satellite data is utilized, but it is processed by TVA's Mapping Services Branch. The attribute data utilized in projects comes from the various entities within TVA or other clients of Geographic Information Services.

Due to the fact that most of the data development costs are carried by the system clients, it is not possible to provide much information on data costs. However, an example can be given for a large reservoir development project plan. For the project involving Watts Bar reservoir, a total of $270,000 has been spent on the multiyear project to date. Of that amount, about$180,000 has been for database development with the remainder going for analysis and project management.

2.1.6 COSTS

The TVA GIS costs can be readily broken down into the areas listed in Table 2-4. Major costs are system acquisition, labor, maintenance, and initial training.

These costs result in an annual operating cost of approximately $1.1 mil. The funding comes strickly for services performed for other TVA branches and outside clients. In order to be cost effective, the system must be utilized more than one shift.

2.1.7 PERSONNEL

As indicated in Figure 2-1 the Geographic Information Services staff is broken into operating and applications groups. The total number of personnel is currently 17 but the

Table 2-3 Summary of GIS Capabilities- TVA System

Process	Observations/ Comments
Data Entry	* Data entered via digitization * Automatic scanner cost too high to justify use * Cell encoding and topological data structures not supported by Intergraph * Landsat data entry not in use but could be with proper software
Data Editing (1. Spacial)	* Typically plot done at map scale with visual overlay on light table * Interactive screen editing * "Health Checker" software very good * Sliver removal: slivers not allowed by data entry procedures * Polygons below minium size can be eliminated to remove slivers in overlaying * Edgematching routine only fair, problems avoided by procedures * Arc to polygon conversion supported * Editing of three deminsional coordinates * Pan and Zoom for browsing and windowing * Query window generation very flexible * Can view current file plus three reference files
(2. Attribute Data)	* Excellent boolean attribute data retrieval and statistical summaries, also boolean graphics
Map Generalizations	* Line coordinate thinning, polygon vertex coordinate thinning done by MIZAR * Dropline function
Spacial Computations & Manipulations	* Calculates polygon centroids for labeling * DTM routines are accurate, fast, and allows rapid automatic contouring

Table 2-3 Continued

	* Proximal mapping * Grid to polygon and polygon to grid conversions * 15 different projections * Scale limited only by plotter * Distortion removal by elastic body small angle least squares * Coordinate rotation and translation
Polygon Overlaying/ Related Measurements	* Largest polygon 15000 coordinate pairs * Largest map file 32000 blocks of 512 bytes * No limits for island nesting * Resultant polygons from overlaying allows 18 datasets with pointers back to original with limited statistical capabilities * Dropline function to reduce data density * All measurements, point on point, point in line, point in polygon, polygon with points, polygon on polygon, etc. * Line measurements available in any standard units * Area measurements in any units * Volume measurements in user defined units
Grid Cell Analysis	* Both Intergraph and grid-cell based systems allow overlays * Area calculation overlays * Transportation analysis not available for existing networks * Proximity analysis in both systems * Optimal corridor selection not yet on Intergraph system
Digital Terrain Modeling	* 3D views, crossections, any rotation * Contouring * Slope (%), aspect (degrees), and sun intensity analysis * Watershed computations done with IMGRID * Visibility analysis available via OCTVIEW on IMGRID

Table 2-3 Continued

Output	* Versatec V-80 or plotter * 42" electrostatic color mapping * Calcomp plotter * Tabular output via line printer or Epson * B&W Terminals * High resolution color (1024 x 1280 pixels x 256 colors)
Database Management	* Creation via digitization, interactive editing * VAX OS, 63 levels withiin file * User directories set by project leader * Unlimited windowing & boolean attribute queries, all attributes searchable * Multiple maps readily manipulated by piecing together files
Interactive Graphics	* Windowing, pan, & zoom functions are good * Symbol changes can be done automatically

Table 2-4 TVA's GIS Costs

Cost Item	Amount
System Acquisition	$1,300,000 (1985)
Initial Training	$60,000 training courses $~30,000 labor and travel
Personnel Costs	$600,000 annual including benefits
System Maintenance	$145,000 on-site service on all hardware and system software
Annual Training Costs	$3,000

Tennessee Valley Authority

Geographic Information Services

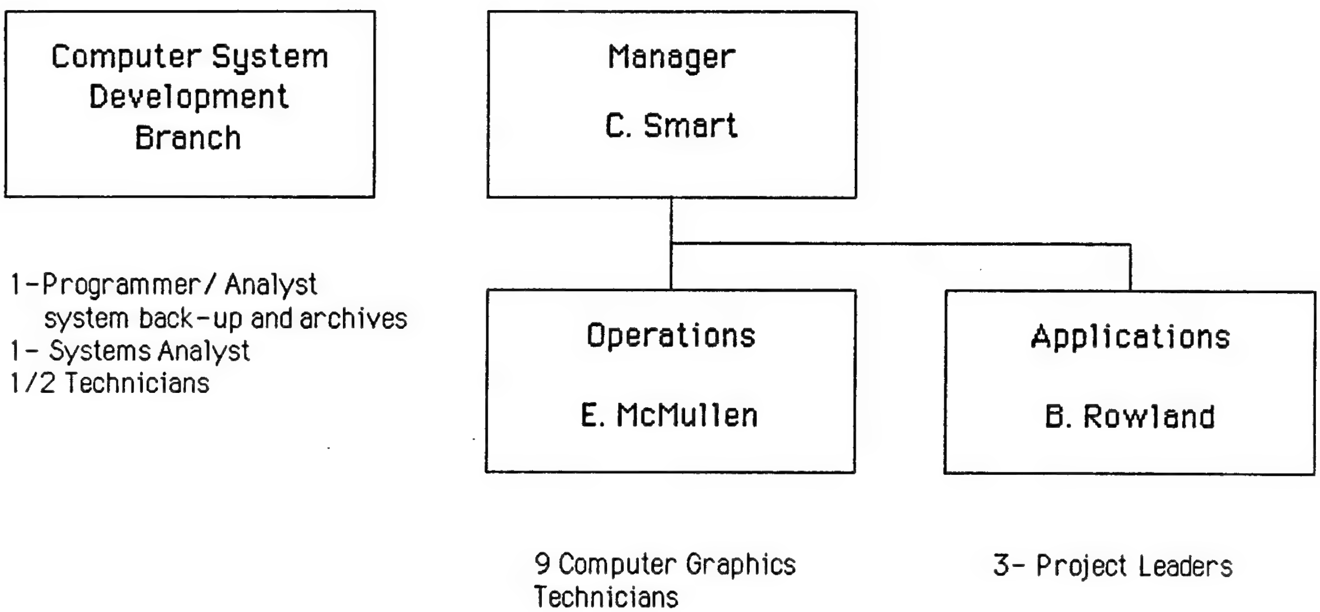

Figure 2-1

staff is short one graphics technician. This staffing should be rather typical of staffing for an organization providing services using a GIS with capabilities similar to TVA 's GIS. The low attrition rate which has been experienced over the past five years is an indication that the staffing and management used by TVA is effective. The only attrition of staff during that period has involved two graphics technicians seeking career advancements in other fields. The only atypical part of the staff organization is that the computer support personnel are in a separate branch.

2.2 KENTUCKY NATURAL RESOURCES INFORMATION SYSTEM (KNRIS)

The KNRIS operates an ESRI GIS to provide services to other Kentucky governmental agencies and to coal mining and other industries. As such it functions somewhat as a service organization, providing databases and graphic products to its clients. The KNRIS has the capability to process both digital and LANDSAT data, but little LANDSAT data is currently used. An upgrade of the system is under consideration at this time, but personnel attrition appears to be a serious hinderance to system operations. The material in the remainder of this subsection covers system hardware and software, management, system capabilities, data and data sources, costs and personnel.

2.2.1 HARDWARE AND SOFTWARE

The KNRIS GIS is an ESRI system which was put into operation in 1981. The system computer is a Prime 750 with 3 MB of virtual memory and 900 MB of disk storage, as well as tape drives for data storage and archival. The system also includes digitizing and imaging processing stations. A list of the major hardware components is give in Table 2-5.

Major software packages in the ESRI system software or used with the system are listed in Table 2-6. These currently operational packages provide capabilities for geographic analysis and display, satellite image processing, database management functions, statistical testing, and engineering analysis.

2.2.2 MANAGEMENT

The management situation at the KNRIS can at best be described as chaotic. Departure of key

Table 2-5 KNRIS's GIS Hardware (Major components)

Quantity	Item
1	PRIME 750 with 3 MB of memory
3	300 MB Disk Drives and Controller
2	800/1600 bpi Tape Drives
1	300 lpm Line Printer
1	Talos 8482 (36" x 48") Digitizing Table
1	DEC PDP 11/151 Mirco with Dual Drives
1	VT 100 CRT
1	Princeton Graphics 8500 B&W CRT
1	DeAnza IP 5524 Image Array Processor with 512 x 512 x 8 RAM Refresh Memory and 4 Video output channels
1	19" Color Monitor
1	Dunn 631 Color Camera
1	Huston 3-pen Drum Plotter
1	Diablo Teleprinter
5	Hazeltine 1510 Alphanumeric Terminals
8	ADD Regent 60 Alphanumeric Terminals
3	Televideo 910 Alphanumeric Terminals
1	Esprit III Alphanumeric Terminal

Table 2-6 KNRIS GIS Software (Major Packages)

1. FORTRAN and BASIC compilers for the PRIME 750
2. ARC and GRID (ESRI geographic analysis package and display)
3. INFO (database manager)
4. MINITAB Statistical Package
5. Variety of in-house programs for engineering analysis, reclamation feasibility, sediment pond design, surface and groundwater, and others.

Table 2-7 Summary of GIS Capabilities- KNRIS

Process	Observations/ Comments
Data Entry	* Data entered via digitization (all polygon) * Topological data structure used by ARC-INFO * Substantial manual data entry performed * Image processor used along with ELAS to handle LANDSAT data * Automatic scanner not used
Data Editing (1. Spatial)	* Visual editing using health checkers * Sliver removal (elimination routine) used, some problems exist * Island condition or donut polygons are readily handled by software * Arc to polygon conversions supported * Editing of x,y coordinates * Edgematching routines are very powerful * Pan and zoom functions for browsing and windowing * Query window generation available as post processing decision * Multiple graphics file can be viewed
(2. Attribute Data)	* Boolean attribute data manipulations nhandled by INFO, also includes graphics
Map Generalizations	* Line coordinate thinning in file cleanup mode * Dropline routine (eliminate and dissolve) * Edgematching routine works well * Polygon vertex coordinate thinning (clean)
Spacial Computations/ Manipulations	* Routine calculates centroids for labeling polygons * Multiple assignments for polygon classifications

personnel has left the KNRIS without a manager twice in the past couple of years. The site visit did not determine the cause of the personnel atttrition.

The organization nominally consists of an administrative manager, a system manager (operational manager), a programmer/analyst, a system software and database manager, and two graphics technicians. However, attrition has left a staff of four, most of which is very junior. The system has a pool of about 80 users who use either GIS or database services. Project staff often includes these users.

2.2.3 APPLICATIONS

The KNRIS was organized largely to perform analyses related to coal mining and related land management concerns. The associated digitization and maping effort created a large database covering roughly 40% of the state at a resolution of 10 acres. Other projects over the past year have included development of a hydologic network of surface streams in the state, soil mapping, new mining suitability analyses, and modelling sanitary landfill locations. A total of ten projects were performed in the past year. Additional information about the databases which are on the system are contained in the Phase II addendum to the Comparative Analysis Databook.

2.2.4 PROCESS/ CAPABILITIES

The ESRI GIS operated as part of the KNRIS is a full GIS including a mapping system, thematic or statistical mapping, and an attribute database management system, and combinations of these functions. The system also has image processing capabilities, although these are not currently in use. The capabilities of the system for data entry, data editing, data manipulations, data retrieval and output, scale and projection changes, overlaying, digital terrain analysis, grid cell analysis, database manipulations, interactive functions or other capabilities or processes are covered in outline form in Table 2-7.

2.2.5 DATA AND DATA SOURCES

Data used by the KNRIS generally comes either form the existing databases or from data

digitized specifically for the project. Satellite data has been utilized in the past to create the initial databases that KNRIS was chartered to develop, but is not used at present. Generally, attribute data comes from the agency for which the project is performed. Most of the digitization is done by the KNRIS staff. No estimates of the data acquisition costs were obtainable.

2.2.6 COSTS

The ESRI system used by the KNRIS was purchased in 1979. A current ESRI GIS with comparable capabilities costs about $90,000 for the software license plus the cost of a minicomputer and accessory GIS equipment. Hardware costs might be estimated at roughly another $100,000 to $200,000, to produce a total cost estimate of approximately $300,000. If these estimates are correct, then the annual operating cost of $200,000 reported by the KNRIS seems to follow the general observation that annual costs for a GIS are approximately equal to the acquisition cost.

The funding for the KNRIS comes from the state budget. The demands upon the system for quick response and efficiency may not resemble those required for other systems.

2.2.7 PERSONNEL

The staffing situation at the KNRIS at the present time does not represent the desired situation, as two system managers have departed over the past two years. Normally, the KNRIS staff has an administrative manager, an operational or systems manager (for image processing and hardware), a programmer analyst, a system software and data manager, and two graphics technicians. Currently, the KNRIS staff is down to four, who appear to be graphics technicians who have been trained to perform other functions. The cause of the attrition was not determined, but may be related both to state pay scales and lack of challenging work for a motivated individual. Basically, the KNRIS did not turn out to be an optimum choice for examination in Phase II.

2.3 BLM, DENVER SERVICE CENTER

Mr. Bob Adair of the BLM, Denver Service Center was interviewed concerning the MOSS

geographic information system that all of BLM uses. Mr. Adair was, at the time of the interview, heavily involved in a validation effort of the next revision of MOSS. This is the first time that a complete test of all functions will be made before a release to the field. It is important to note that MOSS is only part of the GIS. MAPS, a raster based set of routines, COS, a cartographic output system, AMS, a digitizing system, and IDIMS, an image processing system are also available to the users of the BLM system. MOSS and its associated parts are public domain. IDIMS is a stand-alone image processing system.

The Denver Service center acts as a clearing house of revisions and updates to the field offices. Since it is close to the Fish and Wildlife Service at Ft. Collins, CO, it also acts to coordinate revisions with that organization, another MOSS user. When the resources required to accomplish a given project are not available at a BLM field/state office, the Denver Service Center also acts to provide backup resources.

2.3.1 HARDWARE AND SOFTWARE

The BLM MOSS system runs on Data General equipment. This includes the C330 DG (Eclipse) minicomputer and DG20 microcomputer. Additionally, a HP3000 series 3 is used for IDIMS. As IDIMS is an image processing system that operates in a nearly stand alone mode, it will not be further discussed. It is important to note that a version of MOSS does run on Digital Equipment's VAX series computer.

There are about twenty terminals in use at the Denver Office, this includes a few IBM PC's and COMPAC PC's used as terminals. Presently only one shift operations are maintained, but could be increased if the workload required.

The software for MOSS on the Data General computers is in FORTRAN V. The operating system is the DG operating system common to the equipment. There is no relational database associated with MOSS.

Criticism of MOSS is readily available from non-users. While the MOSS community will

agree that MOSS is in need of updating, there is no indication that the system is incapable of performing the functions necessary for the projects that BLM does. From a user's prespective, the sometimes excessively long run time is only a nuisance.

To summarize the advantages of MOSS is to state these facts, (1) it works, (2) it is public domain so that initial costs are low, (3) there is a wide Federal Government community that can provide assistance in acquisition and training, and (4) there is a wide community of trained users. To summarize the disadvantages is to cite the failings of the MOSS software.

The MOSS community has cited the need for an expenditure of $2 mil to $7 mil to update the MOSS associated packages in order to meet their needs. This indicates that the critisms of outdatedness, inefficiency, and poor documentation have substantial basis in fact. Such a major overhaul also carries the risks normally associated with software development, those of cost overruns, late delivery, and proliferation of software errors. Additionally, it seems from the interviews conducted that MOSS has abnormally long computer run times for most of its functions. While it is capable of the majority of actions associated with a GIS, its performance is that of sixteen bit technology, slow, definitely not the performance normally associated with a minicomputer. Associated with its utilization of outdated technology, it has no database management system. The present system merely is a partially optimized file handling capability. The software itself does not follow normally accepted software engineeering practices; its modules are long; modularization is achieved by subroutine, not functional block; it was originally developed in a nonstructured version of Fortran and has all the characteristics of "spaghetti" code. Software maintenance, even if spread over many government agencies, will prove labor intensive and costly.

These failings make MOSS the only system investigated in Phase II that is beyond a doubt completely outdated and beyond any usefulness in the BMDSCOM comprehensive site analysis process.

2.3.2 MANAGEMENT

The Denver Service Center acts as a support organization to the state offices. It also acts as a

focal point for MOSS software development. They act as a service organization, but since BMD will not have a large number of distributed GIS sites, its organization would not seem appropriate for emulation. One shift operations are run, with the possibility of two shifts if demanded by the workload. As the equipment appeared to be well utilized, it would not appear that three shifts are possible. Maintenance contracts are utilized for hardware maintenance, software maintenance is completed in-house and by Technicolor Government Services, BLM's support contractor. A large portion of the digitizing needs are contracted out. This contracting out of the most time consuming and tedious part of GIS work, digitization, is very cost effective and can be a major cost driver in maintaining a GIS.

2.3.3 APPLICATIONS

The BLM GIS is utilized in support of its various projects. It has been used for resource management plans, environmental impact statement preparation, activity plans such as range plans or forestry use plans, coal leasing, drainage analysis, oil and gas inventory, and mineral inventory. Major efforts planned for the Denver Service Center include mineral inventories and mining claim tracking. The Denver Service Center also is a major center for software testing.

2.3.4 PROCESS/ CAPABILITIES

The MOSS system is capable of handling the functions indicated in Appendix A. It is important to note that MOSS has limited report generating capability, no relational database, no network analysis capability, and no engineering/architecture modeling capability. This would make a MOSS based GIS unusable in the CSAP for the following reasons: (1) overlays, the primary method of exclusionary criteria development, are slow and become exponentially longer as layers are increased because of the lack of a relational database management system; (2) there is a report generating routine, however it only outputs columnar data that would not be much aid in any of the impact analysis documentation; since there is no generalized report generation routine or module, any report form generation would have to be written in code; (3) with no network analysis ability, MOSS could not aid in the optimization of transportation network planning, nor in the analysis of security requirements, or in the development of constraints on personnel or equipment; (4) with no

modeling capability, system analysis will not be aided by the GIS. MOSS does, however, have a viewshed type function called VISTA.

2.3.4 DATA AND DATA SOURCES

Most of the cartographic data used by the Bureau of Land Management is self generated; at field offices, at the Denver Service Center, or by BLM contract. The USGS tapes are also used when data needs overlap. Some data is also obtained from the image analysis section at BLM using the IDIMS system. The initial satellite images are obtained from EROS and the Jet Propulsion Laboratory. Most attribute data is obtained from maps, not field notes. The Denver Service Center does not do any field work directly unless the state offices do not have the resources. Due to its size and complexity, the Denver Service Center is presently supporting several GIS efforts in Alaska.

2.3.6 COSTS

The MOSS software is public domain and is available from BLM or most of its other users for the price of the magnetic tape or less. Due to its need to be upgraded in order to maintain its continued usefullness, this initial low cost will be more than offset by upgrade costs, making any of the commercial packages cheaper in even the short term. The documentation for the software has improved, but software maintenance will still be a concern. The fact that BLM has set up the Denver Service Center as a testing center for software indicates that there are significant maintenance problems. Cost isolation for particular parts of the MOSS system is difficult due to its evolutionary growth, in software, hardware, and personnel. Microcomputer based subsystems have been effectively used as software test stations, and as workstations in a decentralized processing mode. If large numbers of users are envisioned for a BMDSCOM GIS, then this tiered set-up, with the minicomputer handling the large portion of the workload and microcomputers doing simpler, off line problem solving, should be considered as a option for cost reduction.

Funding for the Denver Service Center's GIS comes from a combination of funds for

individual projects and general office funding. The state BLM offices spend the majority of money on data aquisition. The BLM started development and aquisition of MOSS in 1975.

2.3.7 PERSONNEL

The Denver Service Center GIS has approximately ten people working in the applications area, three in the area of systems operations, and three providing programming and technical support. This is supplimented by six contract personnel. The training for a new user consists of a week of instruction followed by six word or case study type problem solving exercises that reinforce practical application skills in the areas of future work; environmental impact, range use or something similar. The GIS section has not had any notable problems in personnel retention, even though the majority of people have been there less than a year.

2.4 ESL GMIS

Mr. Charles Nelson, of ESL Inc., a subsidiary of TRW, was interviewed concerning the GMIS operated for the Air Force's Ballistic Missle Office.(BMO). Mr. Nelson has been an active member of the GIS community for about fifteen years. Previous to his employment by ESL, he worked at the EROS Data Center. In addition to GES/ERIS, the facility also includes an IDIMS system for image processing.

2.4.1 HARDWARE AND SOFTWARE

The GMIS facility operates in both off-site and on-site mode. There are three workstations off-site and three on-site. Design capacity has not yet been reached. Communications between workstations off-site and the HP minicomputers are accomplished over telephone lines and modems. In addition to the workstations, there are twelve editing terminals. The GMIS uses the HP150 microcomputer in both terminal and stand-alone configurations. Additional equipment includes a variety of plotters that allow graphic output in a wide range of sizes. It is important to note that version 8.7 of the GES software will be available under VMS for Digital Equipment's VAX series computer. Present operational workload has forced the section to maintain both a HP 3000 series minicomputer and its upgraded replacement. (series 48 and 68 respectively).

The GES software is a digitizing package that is extremely flexible. It will accept a wide variety of input devices including the normal digitizing tables with an assortment of pens and digitizing pucks, and crosshairs on a terminal display. The output routines are equally flexible, interfacing to a majority of commercial plotters. The six stages of use in digitizing in GES are (1) initialization, (2) map registration, (3) data entry, (4) data display, (5) data editing, (6) output plotting.

The GES uses an interface to the Earth Resource Information System (ERIS), which acts as the database and database manager. Up to twenty overlays can be handled in each geoblock. The geoblock structure is a sophisticated adaptation of a polygon/cell data structure. Due to its unique design, the majority of the problems associated with polygon/ cell structures are avoided. Cell search is optimized through the use of a junction pointer file that narrows the search to a quick few. An internal coordinate scheme make high resolution data easy to use and manipulate. However, there are limitations in this design. The GES and ERIS are stand-alone parts that require interfaces for functions that require both map data and attribute data. The data of only one geoblock can be referenced at a time. If in project design, an error is made in the coverage of a geoblock, the analyst is required to go through a complicated and time consuming process of matching/copying data into and out of ERIS files in order to enlarge the area coverage. The GES system can only access one ERIS file at a time, again making project design unforgiving. It could be argued that a database manager that allows access to only one file at a time is not a database manager. While the ERIS is a relational-like database system, its table design makes it use pointers or flags to subtract unwanted information. It is required to mark the data, then save to disk, then recall, in order to be somewhat timely in the purging of unwanted information. Additionally, ERIS makes intermediate tables or files called "cases" to store boolean operation results. This is not an efficient relational design.

GES, in addition to interfacing ERIS, also interfaces part of the USGS general cartographic transformation package. This allows the use of eight of the twenty available map projections. The majority of this package is transparent to the user and gives more than

enough capabilities for all but cartographic research projects. There are also interface/ utilities for transforming the USGS's digital line graph data into GES usable formats.

2.4.2 MANAGEMENT

The GMIS office is run as a service bureau for the Air Force's needs. The Site and Environmental Group develops a project and then the GMIS office accomplishes the tasks. The diversity of plotters is necessitated by the need to respond to a wide variety of requests. As the software is proprietary, it is internally maintained by ESL. Difficult or time consuming software projects are handled at the Sunnyvale, CA office. Hardware maintenance is accomplished in-house when possible. Currently, the office is operating about one and a half shifts, but this varies with the workload.

2.4.3 APPLICATIONS

The present project of the GMIS office is a full US screening of geological information. There is also an on-going project to digitize all of the air bases in the US down to facility engineering scale. In the resent past, a mid-level resolution study for mobile launchers was conducted. The primary purpose of the GMIS is to support the Air Forces' BMO.

2.4.4 PROCESS/ CAPABILITIES

The ESL GMIS has the capability to be extremely beneficial in the application of an exclusion criteria to aid in the narrowing of land to be considered for a facility or site. It overcomes most of the problems associated with cell or grid processing through the use of a unique data structure, called a geoblock. Like most cell based systems, overlay processing will slow at a rate greatly in excess of the increase of the number of overlays. Ten overlays will take much more than ten times the time required for one overlay. The site analysis process will probably not exceed the limit of twenty overlays for each geoblock. The use of overlays will also prove beneficial to the preparation of environmental impact statements. The unique use of internal coordinates also allows the GMIS to be used for most facility, construction, and master planning needs at a large number of different scales. However, the use of this system to aid in the engineering design of road networks, transportation networks, and systems modeling is questionable. A cell data structure is not usually suited for these functions.

Table 2-7 Continued

	* Polygon to grid and grid to polygon conversions * Scale changes * Transformation of digitizer inch to UTM coordinate system * Distortion removal by least squares routine * Project changes supported * Coordinate rotation and translation
Polygon Overlaying/ Related Measurements	* Largest polygon 500 coordinate pairs * Acreage calculation good * Perimeter calculations * Up to 10 files can be linked via a relational item * Measurement computations done using arcs and nodes * Distance measurements in any standard units * Area measurements in any standard units
Grid Cell Analysis	* Grid cell overlay and composite maps * Area calculation overlays * Distance and accessibility determinations * Optimum corridor selection (GRID)
Digital Terrain Modeling	* 3D views, crossections, any rotation * Contouring * Watershed Computations (NETWORK)
Output	* 36 " electroststic color mapping * B&W or color maps from pen plotters * Tabular output via line printer * Interactive 512 x 512 x 3 color CRT with zoom feature * Production of computed data files

Table 2-7 Continued

Database Management	* Creating via digitization, interactive editing * PRIME OS and utilities * User directories set by project manager * INFO has full search and retrieval * Edgematching * Unlimited boolean features and attribute queries * Easy conversions between grid cell and coordinate (both directions)
Interactive Graphics	* Windowing, pan and zoom, symbol changes (ARC-PLOT) * Editing- rotation, transformation, anlargement, deletion

2.4.5 DATA AND DATA SOURCES

The cartographic data is a combination of in-house and contractor supplied digitization. Original maps are from a variety of sources from within the responsible agencies of the federal government. They have used LANDSAT and thematic mapper data tapes for image analysis and GIS input. Attribute data is obtained mainly from paper maps and image analysis.

2.4.6 COSTS

All questions about cost were refered to Mr. Robert Hall, (408) 738-2888. He has chosen not to respond in time for inclusion in this report. From the Phase I questionnaire, the GMIS initially cost about $500,000 in 1982. Annual operating and maintenance costs were considered proprietary and were not released during the Phase II interview.

2.4.7 PERSONNEL

There are twenty-three people in the GMIS office, of which fourteen have the job of operating the system. Training time on the system usually is about a week if training only and about a month if concurrent with other responsibilities. The training costs are not isolated. It is policy to try to send each individual to a GIS conference or related seminar every year. This aids in maintaining morale and expertise. The GMIS office has not had any problems with retention, and in fact appears able to attract and hire experienced people whenever needed. System maintenance is the only function that requires any early hour work.

2.5 US GEOLOGICAL SURVEY

Mr Stephen Guptill, National Mapping Division (NMD), was interviewed in reference to his experiences in the National Mapping Division with various GIS's. USGS operates three of the four systems that were chosen for Phase II of the Comparative Analysis of Geographic Information Systems; Intergraph, MOSS, and ARC-INFO.

2.5.1 TYPICAL USGS SCENARIOS

A typical scenario for a "GIS job" would be this: LANDSAT data would be analyzed using IDIMS, an image analysis package with a capable GIS sub-package. Some overlaying and analysis is performed, if necessary other digital information is transferred over to raster form and used. A final hardcopy product is made. An alternative scenario would be to digitize information using the INTERGRAPH system, in their experience the best for digitizing and creating files. Then the information would be transferred over to ARC-INFO for any analysis. Depending on the final product desired, the hard copy output would be produced either using the ARC-INFO system or INTERGRAPH system.

2.5.2 COMMENTS ABOUT SYSTEMS AT USGS

IDIMS is more than just an image processing system. It is raster type, and "quite usable". It will be used in the Federal Mineral Lands survey catagorizing mineral potential. It is good for all but network type analysis.

MOSS has a large government user community. The reason that USGS has MOSS and its associated packages is that they must be able to interact with BLM, FWS, and other government users of MOSS. It is outdated, outmoded, poorly engineered, costly to maintain, and many functions still have not been updated to take advantage of 32-bit computers. It is not very good, and a recent letter protesting FWS continued procurement and support of MOSS had many valid critical points.

INTERGRAPH has not been used by the USGS for any GIS work, but rather for digitizing and as a tool for mapping functions. In this area, it is superior to anything else available. Its strength is that the Intergraph system is a CAD/CAM system that is very good at mapping. There are questions concerning its analysis capabilities that have not been resolved by USGS. The speed associated with the Intergraph system is very good.

USGS experience with ARC-INFO is relatively new. The NMD has completed a major demonstration of its capabilities as a site analysis tool in Connecticut, overlaying layers of geological, hydrological, transportation networks, minerals, etc. as an exercise of the

system. It has many more functions available than MOSS, due to its superior data structure. The demonstration was digitized and then transferred to ARC-INFO, as digitization is a weak area for ARC-INFO.

The trend in GIS data structures is that topological information is best analyzed in an arc-node manner. ARC-INFO does that. There was, however, a recent demonstration by Synercom at USGS that was favorably received. Synercom has purchased the rights to ODDESSY, an orphan arc-node system developed at Harvard University. This means that ARC-INFO is no longer unique in its use of an arc-node data structure. Most R&D in the GIS field involves arc-node data structures. Of the systems at USGS, ARC-INFO is the current leader. Based on the Synercom demonstration, a good bench mark test would be required to determine which is better, ARC-INFO or Synercom. The database used, INFO, could be more closely intergrated, and it is not as good as some other, stand-alone DBMS available for minicomputers. The compatabilities between the VAX and the PRIME versions are not as good as they could be. There was a slight problem in transferring data over during the Connecticut demonstration. (USGS runs ARC-INFO on both Vax and Prime minicomputers). Also there is some concern over the segmenting of software packages by ESRI. The danger is that in unbundling software for marketing reasons, incompatabilities between software packages could cause a lack of integration.

2.5.3 DATA AND DATA SOURCES

USGS conducts training on a wide variety of GIS sytems. The section does not operate as a service bureau, but rather teams with other divisions for specific projects.

DMA passes mapping requirements in the US through USGS. John McLaurin, a program manager in Digital Cartography, is the responsible individual to ask specific questions on digital tape availablity. (1-703-860-6221). Most current effort within the NMD is with the Census Bureau in the coverage of the US for most mapping data, in digital form at a 1:100,000 scale. The project is due for completion in 1987. Some 30 min by 30 min blocks will be available this year.

Table 2-8

Essential INFO Commands

ADD	adds data records to an INFO file
CALCULATE	computes the value of an arthmetic expression and stores that value in an item for the selected INFO file records
DEFINE	creates a new INFO file and specifies the item definitions of the new file
DIRECTORY	lists the set of INFO files in an INFO directory
ERASE	deletes a selected INFO file
EXTERNAL	specifies, changes, or cancels existing pathnames for external INFO files
GET	loads data from a disk file into an INFO file
ITEMS	lists the item file definitions of an INFO file
LIST	lists the records in an INFO file
MOVE	replaces the contents of an item with a source item or value. It is often used for adding and modifying character data
PURGE	deletes currently selected records from an INFO file
REDEFINE	allows item definitions to be redefined using existing item definitions. Redefined items are added, existing item definitions are not changed.
RELATE	establishes a relationship between records in two INFO files using values for an item found in both files. A record from one INFO file is related to a record from another file which has the same value for the common item. Up to ten INFO files can be related together at one time.
RESELECT	selects a subset of records from an INFO file which meets a user-specified set of conditions. The conditions are specified using logical and arithmetic expressions.
SELECT	selects an INFO data file for further use.

Table 2-9
ARC Commands from ARC User's Manual Jan 85

Command	Description
ADDITEM	add INFO item
APPEND	merge coverages
ARC	start ARC
ARCDLG	convert coverage to DLG file
ARCIDC	convert coverage to PIOS format
ARCLABEL	add arc labels
ARCPLOT	start arcplot
BATCH	run ARC as batch job
BUFFER	generate buffer around features
BUILD	create topology
CLEAN	split and clean arcs; create by overlay
CLIP	clip features by overlay
COMMANDS	list ARC commands
CONTENTS	list coverage features present
COPY	copy coverage
coverages	
COPYINFO	copy INFO file
COUNT	list number of coverage features
CREATE	create coverage
CREATELABELS	create polygon labels
DELETETIC	remove selected tics
DIGITIZE	digitize new coverage
DISSOLVE	drop selected polygon boundaries
DLG3ARC	convert DLG Standard Format file to coverage
DLGARC	convert DLG Optional Format file to coverage
GENERATE	create new coverage features
GRIDPLOY	convert data in grid format to coverage
HELP	list help for ARC commands
IDCARC	convert PIOS file to coverage
IDEDIT	update feature User-IDs
IDENTITY	add coverage features topology
INFO	start INFO
INTERSECT	intersect features by overlay
JOINITEM	merge INFO files
KILL	delete coverage
LABELERRORS	list polygon label errors
LABELMAP	plot coverage with labels
LINEGRID	convert coverage arcs to grid format
LOG	list commands used on
MAPJOIN	merge adjacent coverages
MNODE	match nodes and weed coordinates
POINTGRID	convert coverage points to grid format
POLYGRID	convert coverage polygons to grid
PROJECT	change coverage projection
QUIT	exit ARC
REBOX	redefine coverage BND
RENAME	rename coverage

Table 2-9 Continued

Command	Description	Command	Description
DROPITEM	drop INFO item	RESELECT	select subset of coverage features
DROPLINE	plot polygons with selected boundaries dropped	SNAPCOVER	match and adjust coverage features
EDGEMATCH	match edges between adjacent coverages	SPLIT	split coverage into many coverages
EDIT	edit/digitize an existing coverage		
EDITPLOT	plot coverage with diagnostics	SYMBOLMAP	plot coverage with special symbols
ELIMINATE	delete selected polygons		
ERASE	delete part of coverage	TOLERANCE	define or list coverage
tolerance			
EXTERNAL	externalize coverage INFO files	TRANSFORM	transform coverage
coordinates			
EXTERNALALL	externalize all INFO files in workspace	TRAVERSE	enter surveyed traverses
		UNION	combine by overlay
	UPDATE	cut-and-paste polygon features	

3.0 COMPARISON OF PHASE II GIS SYSTEMS

During the Phase II investigation certain similarities and contrasts between the different GIS were made. These are summarized in this section.

3.1 HARDWARE AND SOFTWARE

Sites were visited that ran minicomputers representative of the following hardware vendors: Hewlett Packard, Data General, Prime, and Digital Equipment. It is apparent that no one machine has any marked advantages over another. All seem acceptable. The experience of both TVA and ESL suggests the sometimes not so obvious, that is, the greater the capacity of the machine, the greater the ease of GIS applications. Both have experienced upgrades in the recent past, TVA to a VAX 11/785 and ESL to a HP3000 series 68.

The following is a suggested base of hardware for a functional GIS:

a mincomputer with as much memory as budgeting will allow
disc drive units
streaming tape units
a backlit digitizing board
pen plotters
high resolution graphics terminals
electrostatic plotter
printers
dumb terminals for alpha-numeric editing
some image processing system

All sites visited had some vendor specific combination of the above. Calcomp, Versatec, and Tektronics were common names for vendors, but any comparable source should be acceptable.

Software comparisons are the basis of choice for our recommendations and are covered in section 5.

3.2 MANAGEMENT

Based upon the site interviews, it is readily apparent that all of the GIS systems function as service organizations. They serve either other entities within their parent organization, or other agencies, or both internal and external clients. The major differences which influence management involve the volume of work performed on the system, the mechanism by which funding occurs, and the staff organization.

All of the systems appear to have several characteristics in common. One is that all have heavy workloads. Yet, it appears in the case of the KNRIS, that that system has gone through some change in its basic mission which influenced personnel professional satisfaction. Part of this may be that the work of the KNRIS changed to a database management function and not an analysis function. For whatever reason, although the personnel titles are similar within different organizations, the organizational and functional roles of the personnel differ substantially. While TVA and the KNRIS have basically similar job classifications, one, KNRIS, has a very narrow vertical organizational structure. Graphics technicians report to an operational system manager who in turn reports to an administrative system manager. The operations manager also has systems maintenance responsibilities, and perhaps even programming duties. In this system, (KNRIS), it was difficult to determine who if anyone was responsible for applications. In contrast, the TVA Geographical Information Services staff has several applications personnel who are responsible not only for analysis and development of applications tools, but who are responsible for marketing services to other TVA departments or other governmental agencies. Also, the TVA staff organization is more horizontal, with the staff divided distinctly into operational and applications groups. This distinct division of labor functions better than the other organizational arrangements noted. Finally, the mechanism for funding may also relate to the successful management of a GIS. A staff which operates as if it were a private service organization may also work better. Staff managers called upon to sell their section's services in order to maintain the workload of a GIS are likely to be more motivated and more creative than a staff funded via state appropriations. They are also more likely to be happy with their jobs if challenged by

interesting and demanding problems. Optimally, a GIS staff is organized in two parts, operations and applications. The part of the staff devoted to software maintenance does not have to be within the same management group, but could be.

One significant management decision involves the digitization of data. If an organization is involved in the initial development of a database, it may prove cost effective to subcontract digitization services. The BLM Denver Service Center has used this approach effectively. Since BMD may initially need to prepare large databases for designated candidate regions involving large geographic areas, use of a service contract for digitizing could prove useful in the initial database creation problems, aiding in both cost effectiveness and personnel workload.

Another critical management decision revolves around maximizing use of an expensive GIS so that the relative cost of a system is lowered by amortizing the costs over more projects . TVA runs two shifts and other GIS systems interviewed do the same on occassion.

3.3 APPLICATIONS

All of the systems examined in the Phase II site visits perform a broad range of GIS functions. All have capabilities and have been applied or could be applied to environmental analysis including environmental impact studies. All have been applied to land suitability and siting analysis in some manner. However, in one area especially important to the CSAP process, the GIS applications vary significantly among the different systems. This area involves engineering modeling applications. The MOSS system utilized by BLM is applied primarily to land management and natural resource management applications. Although it has been aplied to some problems associated with siting such as viewshed analysis and hydrologic modeling, the BLM MOSS system can not be applied to a variety of problems including network analysis, transportation analysis and other areas of application needed for system analysis.

The ESL GMIS system is different from the other systems in that it has been applied to uses similar to the BMD CSAP. It is used primarily for support of the Air Force Ballistic Missile

Office. It has been applied to air base facility engineering applications. The construction of the GMIS does not allow it to be readily adapted to network analysis, and systems modeling. Studies for the mobile missile system utilized IDIMS, not GMIS. Applications involving overlays can be rather slow. The major area of application in which the GMIS may have some advantages over other systems is environmental impact analysis. The area of environmental impact analysis has traditionally been performed using cell or polygon structures. The geobased adaptation of the polygon structure appears to be superior to that of other systems, notably MOSS.

The remaining GIS systems, TVA's Intergraph system and the ESRI system used by the KNRIS generally have been applied to similar sets of tasks. Although the capabilities of these systems allow a wide range of applications, there are notable differences. The Intergraph packages needed for specialized applications are more difficult to integrate into the GIS system. Of these two systems, the Intergraph GIS has an obvious lead in performance in the area of design graphics and mapping. The CAD/DAM capabilities of the Intergraph system make it more suitable for engineering design and systems modelling. Finally, there are some applications for which the ESRI system out performs the Intergraph system. These are applications which involve extensive overlaying, in which the arc-node data handling format of the ESRI system currently gives it advantages in speed.

GIS and other software packages operated by TVA have been applied to environmental analysis, resource and land management, siting analysis, and engineering and architectural applications at the facility level or lower. One of the few applications not available is analysis capability for the analysis of existing networks, such as road systems. However, it has been applied to analysis of design of a new networks and to corridor analysis. The main difference between the Intergraph and ESRI systems is that much of the analysis applications used by TVA involve software from third-party vendors or packages from TVA's earlier grid based system. ESRI appears to have moved software packages into its GIS package, perhaps allowing more applications without further additions. However, this software bundling may inhibit software intergration.

3.4 PERSONNEL

It is more appropriate to provide some generalizations about GIS personnel than to contrast the different site findings because the personnel types needed are the same. The types of personnel typically included on all GIS staffs include a GIS manager, operations managers, applications or project managers, applications specialists, software specialists, and graphics technichians. In addition, GIS systems utilizing LANDSAT or other image based data would be expected to have image processing specialists on its staff.

The size of the GIS appears to relate directly to the workload. For example, the TVA operating with a staff of seventeen performed four times the number of projects that the KNRIS performed with a four to five person staff. Since database creation requires a great deal of digitization, the number of personnel required for the database building function is likely to be larger than in other operations . For this reason, it may be wise to contract out much of the early digitization. For updating or unique projects, even a mature GIS operation which has databases has a significant need for graphics technicians. An example is the TVA operation in which half of the personnel are graphics technicians.

Finally, since GIS systems are proliferating, the average experience of most staffs is short, as was reported for the BLM Service Center. The TVA staff retention, especially its more experienced personnel, may be atypical. Often experienced GIS system staff are hired away to staff another system.

4.0 ANALYSIS OF ATTRIBUTES IN RELATION TO THE COMPRHEHENSIVE SITE ANALYSIS PROCESS

A baseline BMDSCOM GIS will be discused in relation to the tasks of the CSAP, followed by a discusion of specific recomendations for a baseline GIS.

4.1 COMPREHENSIVE SITE ANALYSIS PROCESS

The best geographic information system for BMDSCOM would be one that could accomplish all geographically related functions that could be possible during the site analysis process and still be flexible enough to meet any presently unforeseen needs. The following is an outline of the analysis areas and how a geographic information system could be used in this Comprehensive Site Analysis Process.

The CSAP consists of four major parts, (1) the proposed action identification, (2) the impact analysis, (3) site planning, and (4) execution. This is followed by a post Full Scale Development period. Each of these parts will be discused in terms of either a major use of GIS technology or a limited use of GIS technology.

4.1.1 PROPOSED ACTION IDENTIFICATION

The purpose of this phase is to identify all necessary actions to ensure a timely, cost efficient development of a site. There will be a limited use of the GIS during this phase. The uses possible are mainly in the graphics and information management fields. A relational database that is part of a GIS could be used at this time as a stand-alone database manager in order to assist information processing and control. This would also give a early start in the database development for future GIS applications. Most well developed GIS's also have a substaintial graphics production and output module. This might be useful in the production of graphics for briefings or other presentations. It would, however, be difficult to justify the cost of a GIS for theses needs alone. Due to its outstanding graphics capabilities, of the four systems reviewed in Phase II, the Intergraph system with a third party database, would be the clear leader for the Proposed Action Identification Step.

4.1.2 IMPACT ANALYSIS

Impact Analysis has five major parts, (1) siting impact and validation, (2) costs functions and life cycle costs, (3) operational impacts, (4) logistics, and (5) impact analysis documentation. GIS technology will have a major impact on siting and documentation, and a limited impact on the remainder.

Siting impact, with its use of overlays, determinations of exclusion zones, and investigations of desirable criteria, will be a major driver in the needs for a GIS. In order to be effective, the GIS must be capable of quickly overlaying different exclusion criteria, and rapidly responding to changes in those criteria. For this type of GIS work, the ARC-INFO system is uniquely suited. An intergral part of the system is a relational database, INFO. This means that criteria can be quickly and effectively tested and if neccessary changed. A relational database also means that the data used for producing overlays and exclusionary zones is quickly merged and accessed. Additionally, the arc-node data structure means that multiple overlays are computationally fast. This data structure is the same structure of most digitizing software, making the use of various data files from other government agencies easy to interpret. This structure has also been adapted to network analysis, allowing the use of the GIS to aid in the optimal determination of transportation systems or other analytical routines. Being a topological structure, information traditional expressed in map form is easy to manipulate and analize. Of the four GIS systems examined in Phase II, ARC-INFO is the best for siting impact analysis.

Closely related to siting impact is the validation of the site with the BMD system parts situated in specific locations. For this effort, either the Intergraph or ARC-INFO would be suitable. Intergraph would be usable because of its outstanding graphics capabilities. TVA has used many engineering/ architecture routines from third parties on the Intergraph system that would greatly aid the validation process. ESRI also markets a COGO package of similar routines that is well integrated with ARC-INFO and performs in a similar manner. In order to manage the mass of information inherent in the validation process, a relational database is needed, this could be INFO or another third party product.

The GIS would have a more limited use in the area of cost functions and lifecycle costing. GIS technology has matured to the point that it can be used for various optimization studies. The simplest to relate directly to cost being the generation of a cost surface based on geological and land use characteristics, with the GIS finding the least cost route between two given points. This type of analysis is possible with ARC-INFO. Buffering around a route with the buffered distance being determined by some criteria is possible with all four of the systems investigated. Other types of corridor analysis are available and can be indirectly linked to cost. The other use of GIS for cost studies would be in the production of feeder reports. The report generating package of ARC-INFO would prove beneficial here.

Operational impact would be effected by the GIS in only a limited manner. The primary benefit of a spatially based system would be to allow the simulation of the placement of the BMD system components in a cost effective manner. It would be a relatively low cost operation to simulate and test parts as opposed to actually placing components on the ground. The viewshed analysis is an example of this type of systems engineering simulation. Either Intergraph or ARC-INFO would be usable for this type of use.

Logistics would be impacted in a limited manner from the standpoint that the GIS would be an effective communications tool. The use of maps and charts improves communications, especially when that communication is between agencies and not individuals. The output of a GIS would have value in the express of ideas neccessary for the implementation of effective logistic support. Due to its fine graphics capablities, the Intergraph system would be the logical leader in this area.

The area of impact documentation will be greatly effected by the choice of a GIS. There will be a major need for the production of maps, graphs and charts for all major documents. These documents could include: (1) impact analysis reports, (2) siting analysis reports, (3) site validation reports, (4) operational impact studies, (5) logistics reports, and (6) cost studies. In addition to the production of graphics, with a good relational database, the GIS can serve as a major organizing center for all data and information. Also a report generator from the GIS can provide significant inputs to the final documents. For these

reasons, ARC-INFO is the preferred system studied.

4.1.3 SITE PLANNING

The site planning portion of the CSAP can be described in terms of its output documentation. This includes: (1) environmental documentation, (2) installation and test plans, (3) facilities and building plans, (4) baseline schedule documents, and (5) site activation plans. GIS technology can have a major impact on the cost effective production of environmental impact analysis and plans and on the planning for facilities and buildings.

The need for environmental planning has been a major driver in GIS technology for the past decade. This long association makes the use of a GIS for the preparation of environmental impact statements and plans a logical use. Our Phase I survey indicated that most GIS in use do some kind of environmental or land use analysis. Any of the four systems surveyed for Phase II would be usable in this area. The speed of the Intergraph and ARC-INFO systems would make one of these two systems a logical choice.

Engineering and architectural routines intergrated into the GIS have the possibility of making the GIS chosen of major importance in the preparation of facility and building plans. The interfaces to these sort of routines exists for both Intergraph and ARC-INFO. Intergraph, due to its evolution from a CAD/CAM system, would most probably be the strongest candidate for facility planning.

4.1.4 EXECUTION

Most of the tasks in the execution area can be supported by a GIS. The major impact would be in the areas of environmental assessments and master planning. These tasks all provide input into the Milestone II review. The need for logical analysis and good communications makes the cartographic output of a GIS a natural aid to any briefing or discussion. Those portions of site validation studies that are feeders into the neccessary DOD and DA reviews are also the natural products of a GIS. The primary role of a GIS would be in the support of analytical studies needed for various reports.

4.1.5 POST FULL SCALE DEVELOPMENT

Several tasks that are part of the functions neccessary during the post full scale development period can utilize the support provided by a GIS. Most of these tasks can be support by the outputs of the GIS as an aid to effective communication. Intergovernmental and interagency coordination of efforts is an area where good communication must exist and can be aided by a GIS. Community impact assistance is a natural outgrowth of the economic impact studies done previously. In addition, the databases formed during previous tasks would be of immeasurable benefit to community planners and land use supervisors. The major task of the post FSD period would be that of site activation. The information gathered as the results of the different studies performed in the past would be accessable, organized, and easily used by the in-place GIS. Cost advantages of information organization alone would justify a GIS capablity.

4.2 HARDWARE AND SOFTWARE

At the current time, GIS systems run predominately on minicomputers with only a small number of systems implemented on mainframe or large microcomputers. The minicomputers in use include Prime, VAX, Data General, and HP systems. If there is a trend worth noting, it is that there is a move toward VAX and Prime minicomputers and away from Data General and HP. The Prime is popular for GIS systems because ESRI intially used the Prime for its GIS systems. The VAX is a leading choice because of its speed. Also, Intergraph has developed graphics processors for the VAX minicomputer. ESRI GIS software is implemented on several minicomputers while Intergraph systems are implemented on the VAX. ESL has used Hewlett Packard minicomputers, and MOSS is run primarily on Data General minicomputers. The cost and power of the VAX make it a logical consideration for a BMDSCOM GIS.

The software available in the different GIS packages each has its own set of advantages and disadvantages . These advantages and disadvantages are the principal drivers for selection of one system over another. The individual stong points have already been discussed for each system in section 2. Recommendations and rationale will be presented in section 5.

4.3 DATABASE ACQUISITION

During the CSAP, a considerable amount of data and information will need to be gatherred and generated. It has been determined that this data will be organized into five project-specific information subsystems, (1) a bibliographic database, (2) an automatic data processing subsystem, (3) geo-based information subsystem, (4) management information, and (5) word processing. This will include both digital and non-digital storage mediums. The following section will address the sources of digital data that can be used in the construction of the geo-based database.

Data will be managed in two categories, environmental resource data and engineering design data. Environmental resource data includes: (1) socioeconomic resource data, (2) physical resource data, (3) biological resource data, and (4) cultural resource data. Engineering design data includes (1) geology and soil data, (2) water data, (3) topography, (4) climate, (5) ecology, and (6) man-made structures. All of these catagories can be expressed in digital form.

Socio-economic data can be obtained from the Bureau of the Census. The USGS is involved with the Bureau of the Census in the production of usable digital cartography for census and related statistical data collection. This effort has as its goal the production of digital coverage of the US at the scale of 1:100,000. Completion is due in 1987. An additional source of data that might or might not be digital would be the land-grant universities in particular areas of interest.

Physical resource or land use data is available form many sources. The BLM maintains alot of digital information for use in range management or land use planning at the various state offices. All of the GIS systems reviewed in Phase II can utilize the MOSS formats presently used by BLM. The BLM is also involved in a mineral survey of the US that would supply a large portion of the necessary geological data needed. Various state agencies also maintain databases on land use. The Kentucky Natural Resource Information System visited in Phase II would be a good example.

Biological resource data would greatly overlap the ecological data catagory. The Fish and Wildlife Service would be a potential source of current biological data and ecological expertise. As they use MOSS, their data should be readily transportable. The state offices of the BLM would also be a source of information regarding the range of various wildlife species.

Cultural databases maintained in the various states would be a potential source of digitized data. As this could be both textual and spatial in a variety of formats, the ease of use or transportability is impossible to predict. Gathering of this type of data would best come after the site selection process has narrowed the geographical area of consideration considerably. Several state GIS investigated during Phase I are examples of the types of databases available.

Geological and soil data can be obtained from the Soil Conservation Service and the USGS. As USGS serves to establish many of the standardized formats for spatial data, all of the systems investigated during Phase II can use USGS data. The handbook, "Guide to Obtaining USGS Information" was included as part of the Phase II databook. The USGS can be a useful source of digital and non-digital data in the areas of hydrology and topology also.

Climate data is maintained by the NOAA at the National Climatic Data Center, Asheville, North Carolina, 28801. This is also a source of satellite image data. The majority of climatic data available appears to be in non-digital media.

Man-made structure data can be linked to its geographic location through a GIS. This would require the digitizing of the information by the operators of the GIS.

The GIS database would be built in two ways, (1) collecting and cataloging presently utilized digital data from other agencies, and (2) digitizing of data by the GIS operators. A cost effective method of obtaining that digitization used by three of the four Phase II GIS's, was to contract out this tedious work. TVA does not contract out this digitization in order to maintain high data standards. Regardless of the method used to obtain data, some editing for

the specific task at hand will be necessary, and the capacity for internal digitizing and editing must be present in the GIS. The acquisition of data can become a major cost driver in the maintenance of a GIS.

Output considered for the information subsystems includes: (1) text, (2) tabular, (3) cartographic, (4) graphic/ thematic. The GIS can support these forms of output primarily in the last three catagories. Due to its report generating module and relational database, ARC-INFO is the logical best choice for this area.

4.4 MANAGEMENT

The management of a GIS appears to be influenced most by two facts. First, is that GIS system costs (capital startup) are not trivial. The second is that costs can be minimized chiefly by keeping a GIS running as much as possible. The best way to do this is to operate a GIS as a service organization. Thus, a principal driver becomes responsiveness to user or client needs. In examining the GIS operations in Phase II, it appears that an organization similar to that used by TVA (Figure 2-1) is well matched to GIS management. This is due to the separation of operational and application functions in a manner which clearly defines a workable division of labor. It is reasonable for BMD to manage a GIS much like TVA does, as it would essentially be servicing other BMD entities during the CSAP.

Another aspect of consideration is the personnel job descriptions and responsibilities. Again, the TVA GIS could serve as a suitable model.

5.0 RECOMMENDATIONS

Based on the five Phase II interviews and the discusion of the attributes of a GIS applicable to the CSAP, two sets of recommendations are made. The first recommendation is to acquire ARC-INFO as the basis of a BMDSCOM GIS. The second, applicable only if acquisition of a GIS is delayed for over two years, is to conduct a benchmark test among the technology leaders in GIS, ESRI, Intergraph, and Synercom.

5.1 IMMEDIATE ACQUISITION

Rationale for an immediate acquisition of a specific GIS is possible because of the current state of the GIS community. The public domain version of a GIS, MOSS, has been clearly surpassed in functions and capabilities by all commercial products. Conflicting data structures that in some cases limit usability, are represented by the remaining possible systems. The data structure that allows the best implementation of a GIS is only offered by one vendor in a proven, tested design. This allows a superior choice that also happens to be a cost effective choice.

5.1.1 RECOMMENDATIONS

ARC-INFO is the best system for immediate acquisition for the following reasons. First, it has a better data structure that permits faster and more varied computations. Second, ARC-INFO runs and has been extensively tested by third parties on the VAX, Prime, and Data General minicomputer hardware. Third, its use of standard software engineering techniques and a common, standard language, FORTRAN 77, expedites interfacing with other software routines and file formats. Fourth, it uses a relational database that is state-of-the-practice. Fifth, ARC-INFO has the capacity to permit engineering modelling and network design. Sixth, it uses standard USGS formats for all data transfers.

The data structure is based on an arc-node concept. This is the natural method of expressing a topology. It is the form that is used for every major digitizing scheme, and it is the form used for the USGS digital line graphs. Due to this form, ARC-INFO is much faster in

overlaying various layers than either the geoblock system of ESL or the graphics based structure of the Intergraph GIS. This data structure of arc-nodes will be the form of all major systems in the future. Synercom's Odessey based system is of this design and Intergraph is rumored to be working on a topological system that is also arc-node based. Presently, ARC-INFO is the only arc-node system that would not mean taking the risk of being a test site.

ARC-INFO has been quickly adapted to all major minicomputers because of its text book use of software engineering techniques. There is no development risk involved with ARC-INFO because of its large, world-wide installed base. The use of standard practices and a standard language means that ARC-INFO will be as easy as any software package to maintain and interface. The use of a stand-alone database manager also means that interfacing can be accomplished on several levels.

The use of the relational database, INFO, also ensures that the advantage of speed available through optimized boolean operations is available to the GIS. This speed advantage also extends to the merging of attribute data when overlays are made. Being a stand alone product, the influences of the highly competative database market ensures that it will be improved and maintained at a state-of-the-practice level. It is superior to the ESL database and at least as capable as the DMRS used by Intergraph.

While ARC-INFO's COGO package is probably not as mature a CAD package as available on Intergraph, it is sufficiently capable for the facility and civil engineering functions invisioned for the CSAP. The network package is unique and definitely an asset for potential facility and system siting.

To summarize, ARC-INFO has the capabilities needed for the CSAP. Intergraph is the closest competition due to its superior graphics and CAD packages. The cost of these comparable GIS systems is about $250,000 for an ARC-INFO system and $1 mil for an Intergraph system, making the ARC-INFO system a superior choice in cost effectiveness.

5.1.2 PROCUREMENT COMMENTS

It should be noted that a number of other government agencies have recent relevant GIS procurement experience. During conversations with Mr. Bruce Rowland at TVA, he indicated that TVA would upon request provide a copy of the procurement documents used in its recent system upgrade. Additionally, he stated the TVA could also point out how their procurement document could have been even better. Several other government personnel were identified in Phase I that could provide similar assistance.

5.1.3 STAFFING RECOMMENDATIONS

Based on the observations made as part of Phase II, it is possible to make some general suggestions or recommendations about staffing a BMD GIS. The staff personnel should fit one of the job titles listed below:

GIS system manager
Manager of the operational staff
Manager of GIS applications staff
Computer operators/ analysts
Applications specialists
Computer programmers
Graphics technicians

The staff could be organized similar to the TVA organization presented in subsection 2.1.2 (Figure 2-1).

Regardless of the organizational structure selected by BMD for GIS operation, someone with prior GIS operational experience should be recruited . There are many people who are experienced on GIS and could be the GIS System Manager. Experience as a manager on one GIS is equally applicable to another.

Applications staffing would best be done by using individuals familiar with weapons systems siting, individuals with land use planning or environmental analysis experience, and

experienced systems modeling person to fill the applications staff positions. The indiviuals filling these positions should be computer literate and have enough background to work with programmers in designing specialized software or software interfaces.

The operations staff should include a programmer/computer analyst with experience on the minicomputer used for the system. Additional programmers should have some graphics background and preferrably FORTRAN 77 experience. Staff size can be minimized by utilizing programmers from outside the GIS staff during peak programming loads. Finally, graphics technicians can be trained quickly. At times when digitization loads are heavy, such as during initial database creation, the digitization load can be handled satisfactorily either by contracting out to private organizations or perhaps by utilizing part time labor. A large portion of the GIS staff should be expected to be graphics technicians, if databases will be constantly expanded in number or size.

5.2 DELAYED ACQUISITION

If acquisition is delayed for over two years, the present advantage enjoyed by ARC-INFO and its vendor, ESRI, will most probably not be the same. Certain considerations and future trends need to be recognized if procurement of a GIS is delayed.

5.2.1 FUTURE TRENDS

The first trend to recognized is that all of the three industry leaders are committed to future improvements and enhancements. Additional capabilities and functions can be expected in terms of functions and performance. Second, the data structure superiority of arc-node forms has been identified by others, Synercom already having adopted it in a not as yet widely used system and others rumored to be working on similar products. This suggests that the trend discovered in Phase I is still applicable, that the GIS community is rapidly changing and constantly improving. Third, Intergraph has superior graphics capability and can be expected to have the resources to finance research and development in its weaker areas, improving its relative stand. It can also be expected that Intergraph will retain its traditionally high price. Fourth, Synercom's recent sucessful demonstration at USGS means

that their product should be considered in any future benchmark testing. Due to its lack of installed base, it would not be prudent for BMDSCOM to accept the risks of using Synercom's software.

5.2.2 BENCHMARK TESTING

Therefore, it is logical to suggest that the recommendation of acquiring ARC-INFO be tempered if the time for acquisition is delayed for a significant amount of time. If such a delay occurs, a benchmark test would be appropriate. Due to the unique blend of attributes needed, such a benchmark should consist of a sample CSAP case study with appropriate measures of performance obtained for each function and appropriate weights for various characteristics assigned. The main areas of GIS application for CSAP, site selection, land use, environmental impact, and system modelling, should be adequately exercised in a benchmark including several major systems. A comparison of operational characteristics and performance should be made as part of a delayed procurement.

6.0 Bibliography

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Appendix A

Questions for Phase 2 interview, date of interview 14 June 1985

GENERAL

1. Name of GIS- *TVA GIS*

2. Name of respondent- *Bruce Rowland*

3. Phone- *(615) 632-6450*

MANAGEMENT

How does your organization manage your GIS ? *see copy of attached chart*

Do you operate mainly as a service bureau for the rest of your organization or is your GIS administered in another manner ? *yes*

Who maintains your system's software ? *confirmation is done internally with some help from INTERGRAPH, other work through the user's group*

Do you utilize a hardware maintenance agreement ? *on-site hardware person from the vendor*

APPLICATIONS

What are some of the major projects where you have utilized your GIS ? *Very broad, 48 projects in 1984, regional to a few hundred acres Applications include reservoir plans, site screening, individual site inventory, gypsy moth inventory, forest (biomass) analysis.*

What major projects do you have planned for your GIS ? or Where are you going from here ? *more detailed land management from districts, more CAD functions, architecture and digital terrain modeling*

How would you classify your GIS ? (as a engineering mapping system, a parcel information system, thematic or statistical mapping system, image processing system, combinations ?) *all except an image processing, which is available from third parties like ERDAS or I^2S*

PROCESS

How does your system handle the following techniques of spatially located geographical data ?

1. cell encoding- *no capacity, only as polygon*
2. topological coding- *not supported by INTERGRAPH*
3. manual digitizing- *yes*
4. automatic entry device (like from Landsat)- *don't use, but possible*
5. automated scanner- *no*

How does your system handle the following processing or editing steps ?

1. plotting for visual editing- *plots/overlays at map scale, can edit interactively using health checkers*
2. topological checking of data- *not using raster data on INTERGRAPH, the INTERGRAPH package has very good checking software*
3. splinter removal- *sliver removal, usally a function of data entry, not allowed, done procedurely; during overlay, ignore those below an excluded size*
4. donut polygons- *island condition, does correctly handle area calculations, both a yes and no answer*
5. conversions of arcs to polygon- *yes*
6. editing of X,Y coordinates- *yes, x,y,z*
7. edge matching analysis- *INTERGRAPH does have a routine, not very sophisticated*

ATTRIBUTE data- very sophisticated entry checking

How does your system handle the following manipulation techniques ? *all can be done interactively*

1. browsing- *pan and zoom functions for browsing and windowing*

2. windowing

3. query window generation- *yes, very flexible*

4. multiple map sheet query- *yes, very powerful (relates to graphical data base)- can view current file and three reference files , later software can handle 32. Master data- any one of over 1000 files can be brought up in part of in total*

5. boolean attribute retrievel and statistical summary- *very good, also boolean graphics*

How does your system handle the following map generalizations ?

1. line coordinate thinning *for stream mode digitizing, commercial product available from MIZAR in Denver*

2. drop line- *yes*

3. edgematching- *essentially handled during editing, the INTERGRAPH edge mathching routine is not real good*

4. thinning polygon vertex coordinates- *not INTERGRAPH, MIZAR's*

How does your system accomplish

1. calculation of centriods- *defines centriod of range box, uses it to label polygon*

2. automatic contouring- *yes, part of DTM, very good, fast, accurate, large volumes*

3. proximal mapping- *proximity analysis, yes , polygon inside/ outside/ both*

4. reclassification of polygons-

5. conversion of X,Y coordinates location data to a regular and uniform grid *works both ways, 15 projections, polygon to grid - uses center dot, absence/ presence, predictive type*

Does your system accomplish the following manipulations ? *can input using different scales*

1. scale change- *yes, only limitation is plotter size*
2. distortion removal by rubbersheeting or linear transformation- *yes, elastic body, small angle least squares*
3. projection changes- *can convert all 15*
4. coordinate rotation and translation- *yes*

What are the limits of polygon overlaying and dissolving for your system ? address overlays for area calculations and statistical analysis- *acreage is very fast, does perimeter, handles islands; statistical analysis is limited.*

1) related to limits of system, largest polygon is about 15000 coordinate pairs, largest map file 32000 blocks (512 bytes/block)

2) no practical limit for island nesting

3) resultant polygons of overlays- pointers back to original, 18 links-18 data sets

Describe your system in terms of its capabilities for measurements in

1. points in polygons- *should be seperate analysis*
2. line measurements- *distance in any units, works well*
3. area measurements- *all standard units*
4. volumetric measurements- *in user defined cubic units*

Describe how your system accomplishes the following grid cell analysis

1. grid cell overlay, making composite maps- *in INTERGRAPH or in-house*
2. area calculation overlay- *yes*
3. distance calculations and accessibility determinations- *not on an existing network*
4. optimal corridor selection- *not on INTERGRAPH*

Does your system allow the following digital terrain analysis ?

1. visual displays of cross sections or 3D views- *yes, both with any rotation, complete 3D flexibility*

2. contouring- *yes*

3. slope/aspect/sun intensity analysis- *yes*

4. water shed computations- *not watershed above point*

5. visibility analysis- *not on INTERGRAPH, on another package OCTVIEW where height of blocking things can be entered*

Describe the following output techniques for your system

1. hard copy maps- *8 1/2" x 11" plotter, 42" Versatec color, Calcomp penplotter*

2. statistical tabulations- *dot matrix printers and line printer*

3. displays or interactive CRT's- *B&W alpha terminals, high resolution color/ B&W video displays (1024 x 1280) with 256 colors*

4. production of computed data files

SOFTWARE AND DATA

Describe your system's capabilities for the following data base manipulations

1. file creation and updating- *standard digitizing, interactive updating*

2. file management- *Vax operating system, 63 levels within file, user directories*

3. basic search and retrieval- *all attributes searchable*

4. listing/ display-

5. query of selected attributes- *unlimited with boolean operators*

6. query of selected attributes by geographical areas- *yes*

7. windowing manipulations

8. edgematching of files

9. grouping of multiple maps/files for larger area contiguous map display- *very easy to piece files together with system*

10. conversion from grid cell to coordinate and back- *yes*

Describe the following interactive functions for your system

1. windowing, enlarging, and geographical symbol manipulation- *symbol manipulation - virtually any symbol can be defined, can automatically replace changes*
2. editing of cartographical elements (rotation, enlargement, transformation, deletion)- *yes, scaling*
3. graphical compositing of multiple overlay files- *yes, turning on different levels*
4. overlay of graphic reference grid- *world mapping system- conversions; also has latitude/ longitude grid generation (any grid on any projection)*
5. interactive graphic entry- *digitizing table, keyboard text, coordinate entry, bearing*

Did you buy your system software ? from what vendor ? *INTERGRAPH*

HARDWARE

What computer does your system run on ? *VAX 11/785 modified by INTERGRAPH*

Describe your system's hardware.

Number of workstations, graphic terminals, alpha-numeric terminals, etc.

Do you run more than one system/shift ? Why ? *yes, two shifts for economics*

PERSONNEL

How many people and at what level operate your GIS ? *see chart*

What do you think is a basic set of user skills and how long does it take to train a new user ? How do you train a new user ?- *INTERGRAPH training is 12 weeks, 2 1/2 weeks for DTM, 4 1/2 for Archives, rest for graphics and database*

Have you had retention problems ? *graphics technicians*

What do you estimate your annual training costs to be ? *new system start-up, training courses about $60k, staff time and travel about $30k, or about $100k including salaries*

COST

What was your system acquisition cost and when ? *this year $1.3 Million*

What are your annual personnel costs ? *17 people annually about $600k w/ benefits*

How much do you spend on software maintenance or development ? *2 of the 17 plus one from vendor for hardware and software at $145k*

What is your annual budget ? *$1.1 million*

How do you receive funding ? *contracts internal and external*

How much do you spend annually on data acquisition ? *Watts Bar Res. Project was $270k so far, about $180k for database development*

DATA SOURCES

Where do you get your cartographical data ? *most from digitizing 95%, other agencies 5%*

Do you use satellite data ? How do you obtain it ? *yes but not processed here, from Mapping Services Branch*

How do you get attribute data ? *other branches of TVA or other customers*

Questions for Phase 2 interview, date of interview *24 June 1985*

GENERAL

1. Name of GIS *Kentucky Natural Resource Information System*

2. Name of respondent *Dave Riddle*

3. Phone *(502) 564-5174*

MANAGEMENT

How does your organization manage your GIS ? *basically as a service organization*

Do you operate mainly as a service bureau for the rest of your organization or is your GIS administered in another manner ? *yes for database creation, and for other Department staff*

Who maintains your system's software ? *assistance from vendor over the phone*

Do you utilize a hardware maintenance agreement ? *service contracts with individual suppliers*

APPLICATIONS

What are some of the major projects where you have utilized your GIS ? *8-10 projects per year; types of projects include- stream network, soil mapping, mining suitability, modelling for sanitary land fill locations; Landsat photos are used as back-up*

What major projects do you have planned for your GIS ? or Where are you going from here ? *planning an expansion of capabilities*

How would you classify your GIS ? (as a engineering mapping system, a parcel information system, thematic or statistical mapping system, image processing system, combinations ?)- *all*

PROCESS- *ARC-INFO*

How does your system handle the following techniques of spatially located geographical data ?

1. cell encoding- *strictly polygon data entry, all modeling in GRID*
2. topological coding- *handled by ARC-INFO which features topological*
3. manual digitizing- *a good bit*
4. automatic entry device (like from Landsat)- *ELAS*
5. automated scanner- *no*

How does your system handle the following processing or editing steps ?

1. plotting for visual editing- *health checking*
2. topological checking of data
3. splinter removal- *sliver- eliminate routine- some problems at processing*
4. donut polygons- *not a problem, handled with software*
5. conversions of arcs to polygon- *can be done*
6. editing of X,Y coordinates- *yes*
7. edge matching analysis- *yes, powerful with several routines*

How does your system handle the following manipulation techniques ?

1. browsing- *yes, can readily access data base to examine data*
2. windowing- *in digitizing mode*
3. query window generation- *reselect, post processing decision*
4. multiple map sheet query- *graphically can view multiple files*
5. boolean attribute retrievel and statistical summary- *all done by INFO*

How does your system handle the following map generalizations ?

1. line coordinate thinning- *given tolerance, other points dropped out; file clean mode not digitizing mode*
2. drop line- *yes, dropline routine (eliminate/ dissolve command)*

3. edgematching- *yes, works well; clean/mmode*

4. thinning polygon vertex coordinates- *clean*

How does your system accomplish

1. calculation of centriods- *manual entry- old system; automatic- new routine*

2. automatic contouring

3. proximal mapping

4. reclassification of polygons- *capability for multiple assigments*

5. conversion of X,Y coordinates location data to a regular and uniform grid *both ways.*

Does your system accomplish the following manipulations ?

1. scale change- *yes, with some limitations*

2. distortion removal by rubbersheeting or linear transformation- *transform digitizer inches to UTM by least squares routine*

3. projection changes- *yes*

4. coordinate rotation and translation- *yes*

What are the limits of polygon overlaying and dissolving for your system ?

address overlays for area calculations and statistical analysis- *500 coordinate pairs, acreage- good; perimeter also.*

up to 10 files at a time (INFO)

Describe your system in terms of its capabilities for measurements in

1. points in polygons- *nodes or arcs, boolean specifications allowed*

2. line measurements- *distances in any standard units*

3. area measurements- *any standard units*

4. volumetric measurements-

Describe how your system accomplishes the following grid cell analysis

1. grid cell overlay, making composite maps- *yes*

2. area calculation overlay- *yes*

3. distance calculations and accessibility determinations- *yes*

4. optimal corridor selection- *yes, using GRID*

Does your system allow the following digital terrain analysis ?

1. visual displays of cross sections or 3D views- *yes, with rotation*

2. contouring- *yes*

3. slope/aspect/sun intensity analysis

4. water shed computations- *network package*

5. visibility analysis

Describe the following output techniques for your system

1. hard copy maps- *yes*

2. statistical tabulations- *high speed line printer*

3. displays or interactive CRT's- *resolution 512 x 512 and Zoom feature*

4. production of computed data files

SOFTWARE AND DATA

Describe your system's capabilities for the following data base manipulations

1. file creation and updating- *standard digitizing, editing*

2. file management- *project manager, file naming*

3. basic search and retrieval- *search and retrieve within database*

4. listing/ display- *all*

5. query of selected attributes- *yes*

6. query of selected attributes by geographical areas- *yes*

7. windowing manipulations- *yes*

8. edgematching of files

9. grouping of multiple maps/files for larger area contiguous map display-
with long run time

10. conversion from grid cell to coordinate and back- *yes*

Describe the following interactive functions for your system

1. windowing, enlarging, and geographical symbol manipulation- *arc plot*
2. editing of cartographical elements (rotation, enlargement, transformation, deletion)- *all*
3. graphical compositing of multiple overlay files- *probably not*
4. overlay of graphic reference grid- *any grid on any projection*
5. interactive graphic entry- *digitizing table, keyboard text, coordinate*

Did you buy your system software ? from what vendor ?

ESRI, Minitab, ELAS

HARDWARE

What computer does your system run on ? *Prime 750*

Describe your system's hardware.

Number of workstations, graphic terminals, alpha-numeric terminals, etc.
1 graphics terminal, 1 image processing station, about 20 terminals, and 1 digitizing station

Do you run more than one system/shift ? Why ? *one shift, 4 GIS personnel for databases*

PERSONNEL

How many people and at what level operate your GIS ? *about 80 users and 3-4 staff managers, about six programmers image analyst for a project. Two graphics people on staff*

What do you think is a basic set of user skills and how long does it take to train a new user ? How do you train a new user ? *training done in house*

Have you had retention problems ?- *yes*

What do you estimate your annual training costs to be ?

COST

What was your system acquisition cost and when ?

What are your annual personnel costs ?

How much do you spend on software maintenance or development ?

What is your annual budget ?

How do you receive funding ? *state funding*

How much do you spend annually on data acquisition ?

DATA SOURCES

Where do you get your cartographical data ? *Generally digitize data for specific project, some data included in state database*

Do you use satellite data ? How do you obtain it ? *yes, have used in past, but not much presently; used ELAS*

How do you get attribute data ? *essentially from other agencies for digitization*

Questions for Phase 2 interview, date of interview *17 June 1985*

GENERAL

1. Name of GIS *MOSS/ BLM Denver Service Center, note also includes COS (cartiographic output system), AMS (analytical mapping system) and IDIMS (image processing system)*

2. Name of respondent *Mr. Bob Adair*

3. Phone *(303) 236-0109*

MANAGEMENT

How does your organization manage your GIS ? *this office acts as a support organization to the state offices when they do not have the resources to do a specific project*

Do you operate mainly as a service bureau for the rest of your organization or is your GIS administered in another manner ? *yes, also distribute semiannual updates of software and debugs as necessary*

Who maintains your system's software ? *Technicolor Government Services coordinates most outside functions*

Do you utilize a hardware maintenance agreement ? *uses vendor contracts for maintenance*

APPLICATIONS

What are some of the major projects where you have utilized your GIS ? *resource management plans- where the best locations are for various things; environmental impact statements, activity plans like range plans/ forestry use; will be expanding more into the area of minerals applications- coal leasing, drainage, oil & gas inventory*

What major projects do you have planned for your GIS ? or Where are you going from here ? *mineral applications, mining claims; also involved in a major test of software before release to other BLM offices*

How would you classify your GIS ? (as a engineering mapping system, a

parcel information system, thematic or statistical mapping system, image processing system, combinations ?) *combination*

PROCESS

How does your system handle the following techniques of spatially located geographical data ?

1. cell encoding, *yes*
2. topological coding, *yes*
3. manual digitizing, *yes mostly contracted out*
4. automatic entry device (like from Landsat), *yes , two or three people full time*
5. automated scanner, *no*

How does your system handle the following processing or editing steps ?

1. plotting for visual editing
2. topological checking of data, *yes through the use of AMS*
3. splinter removal
4. donut polygons
5. conversions of arcs to polygon, *yes*
6. editing of X,Y coordinates, *manual digitizing, so no line thinning*
7. edge matching analysis, *no*

How does your system handle the following manipulation techniques ?

1. browsing, *yes*
2. windowing, *yes*
3. query window generation, *yes*
4. multiple map sheet query, *yes*
5. boolean attribute retrievel and statistical summary, *weak in regression*

and cross tabing

How does your system handle the following map generalizations ?

1. line coordinate thinning
2. drop line
3. edgematching, *all done in the digitizing of data*
4. thinning polygon vertex coordinates, *no rubber sheeting, does do weeding- removal of unnecessary coordinates to reduce data*

How does your system accomplish

1. calculation of centriods
2. automatic contouring
3. proximal mapping, *does corridor analysis*
4. reclassification of polygons
5. conversion of X,Y coordinates location data to a regular and uniform grid

Does your system accomplish the following manipulations ?

1. scale change
2. distortion removal by rubbersheeting or linear transformation, *none*
3. projection changes, *uses USGS's package*
4. coordinate rotation and translation, *yes*

What are the limits of polygon overlaying and dissolving for your system ?
address overlays for area calculations and statistical analysis
32,000 coordinate pairs for a map maximum

Describe your system in terms of its capabilities for measurements in

1. points in polygons
2. line measurements

3. area measurements

4. volumetric measurements

Describe how your system accomplishes the following grid cell analysis

1. grid cell overlay, making composite maps
2. area calculation overlay
3. distance calculations and accessibility determinations
4. optimal corridor selection, *does not do*

Does your system allow the following digital terrain analysis ?

1. visual displays of cross sections or 3D views, *does not do geological profiles*
2. contouring
3. slope/aspect/sun intensity analysis
4. water shed computations, *no*
5. visibility analysis, *VISTA analysis*

Describe the following output techniques for your system

1. hard copy maps, *yes*
2. statistical tabulations, *yes*
3. displays or interactive CRT's, *yes*
4. production of computed data files, *yes*

SOFTWARE AND DATA

Describe your system's capabilities for the following data base manipulations *[Moss is in Fortran V for Data General]*

1. file creation and updating
2. file management

3. basic search and retrieval- *no relational data base capabilities*
4. listing/ display
5. query of selected attributes
6. query of selected attributes by geographical areas
7. windowing manipulations
8. edgematching of files
9. grouping of multiple maps/files for larger area contiguous map display
10. conversion from grid cell to coordinate and back

Describe the following interactive functions for your system

1. windowing, enlarging, and geographical symbol manipulation
2. editing of cartographical elements (rotation, enlargement, transformation, deletion) - *by command on the system*
3. graphical compositing of multiple overlay files
4. overlay of graphic reference grid
5. interactive graphic entry

Did you buy your system software ? from what vendor ? *Data General operating system*

HARDWARE

What computer does your system run on ? *Data General*

Describe your system's hardware.

C330 DG (Eclipse) *HP 3000 series 3 for IDIMS*

MV 4000 D7- DG 20's

Number of workstations, graphic terminals, alpha-numeric terminals, etc.
about 20 terminals, some IBM's and Compacs as terminals

Do you run more than one system/shift ? Why ? *one shift, might be two*

shortly due to workload

PERSONNEL

How many people and at what level operate your GIS ?

applications about 10, systems ops about 3, programming/tech support about 3 plus about 6 contractors

What do you think is a basic set of user skills and how long does it take to train a new user ? How do you train a new user ? *week long training course, then six word problems/ case studies involving environmental impact etc.*

Have you had retention problems ? *no, most people here have been here less than one year, no problems with applications people, some trouble attracting software development people*

What do you estimate your annual training costs to be ?

COST

What was your system acquisition cost and when ? *1975 started*

What are your annual personnel costs ?

How much do you spend on software maintenance or development ?

roughly 10 programmers

What is your annual budget ?

How do you receive funding ? *combination of office funding and project funding, mostly comes out of Washington*

How much do you spend annually on data acquisition ? *states spend the majority, about $30k here this year*

DATA SOURCES

Where do you get your cartographical data ? *self generated, USGS, maps from the field, image processing*

Do you use satellite data ? *Yes* How do you obtain it ? *EROS and JPL.*

processed with IDIMS

How do you get attribute data ? *various map sources*

DATA SOURCES

Where do you get your cartographical data ? *combination of in-house and contractor supplied*

Do you use satellite data ? How do you obtain it ? *have used LANDSAT and thematic mapper*

How do you get attribute data ?